number occur amongst *Rotatoria*, but additions are also made to the *Rhizopods*, *Heliozoa*, and *Infusoria*. No new forms appear to have been found amongst the crustacea, mollusca, or fishes.

A third paper deals with the distribution and special natural history of the forms met with, and with the comparison of the plankton at different seasons.

There are no foot-notes through the number, but all references to literature are formed into a numbered table at the end. The plate, which is one of Klinkhardt's, of Leipzig, shows a number of the new forms discovered.

The investigations are almost entirely on the minute floating organisms, as must necessarily be the case at this date with all freshwater work not connected directly with pisciculture.

The British Journal Photographic Almanac for 1893. Edited by J. Traill Taylor. (London: Henry Greenwood, and Co., 1893.)

THIS annual volume contains, as usual, a vast amount of useful information gathered from workers in all the various applications of photography. After a brief summary, in which the editor refers to some of the chief advances made in the science of photography during the past year, mentioning, for instance, Mr. Dallmeyer's telephotographic lens, Mr. Willis's improvement in the platinotype process, &c., he devotes a few pages to "some photographic methods of book illustration." Then come short contributions in which everyone has something special to say, whether it relates to a new mounting medium, a permanent toning bath, or pinhole pictures, &c. They are far too numerous to mention individually, but will be found most interesting reading. "Epitome of Progress" is the title of a series of notes by Mr. Traill Taylor, in which he refers briefly, and in some cases at length, to new methods, remedies, &c., and instruments used in the practice of the art. The formulæ and tables are as numerous as ever, while all the other information, such as lists of photographic societies, &c., have been brought up to date. The volume is copiously illustrated.

Studies in Corsica. By John Warren Barry, M.A. (London: Sampson Low, Marston, and Co., 1893.)

MR. BARRY has twice visited Corsica, the first visit being of less than five months' duration, while the second extended from September 1882 to February 1885. He has thus had ample opportunities for the study both of the island and of its people, and in the present volume he sums up his impressions very brightly and pleasantly. Most readers will probably like best the chapters on life at Ajaccio, but they will also find much to interest them in what the author has to say about the Bush of Corsica and of the Mediterranean region.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

Luminous Earthworms.

I HAVE recently received from a correspondent a statement which is sufficiently valuable to crave public attention. It opens up withal a very fascinating field of investigation, and one which, though it has by no means been altogether neglected by foretime naturalists, is as yet far from being fully understood.

Writing from Richmond, Surrey, the Rev. Alfred Geden, M.A., says:—"I have just heard of a phenomenon in the worm world which is new to me . . . My sister declares that one day last summer, in a village on the Thames, she saw a 'phosphorescent worm,' and describes the creature as about one and a half inches long, worm-like in all respects. My sister is sure it was not an ordinary glow-worm, with which she is perfectly familiar; and, moreover, she called the attention of a cousin to the creature at the time, who corroborates her account. Are there worms in England capable of emitting light besides the glow-worm? If so, are they at all common?"

In reply to a series of questions, I was able to elicit these further particulars:—"It was in a garden in the village of Long Wittenham, near Didcot, on a dark evening in the latter part of September last [1892], or the beginning of October. My sister's attention was attracted by the light on the ground, and she picked the worm up. While she cannot positively assert that she saw it in motion on the ground, it certainly wriggled in her hand. For a few seconds also after putting it down her fingers remained phosphorescent."

The notice of the public, so far as I have been able to ascertain, was first directed to this phenomenon among earthworms by Grimm in 1670, but scientific observation, as we now understand it, was then scarcely known. A century elapsed before any further record was made in the periodicals of Europe which I have consulted, then came a paper by Flaugergues in 1781. This article, which appeared in Lichtenberg's magazine, was written in German. In 1873 Cohn's observations on the same subject were published in the well-known *Zeitschrift für Wissensch. Zool.*, while numerous recent writers have further contributed to our knowledge, especially in relation to the Continental species.

Thus in 1872 an article appeared in the French Annals of Natural Science, by Panceri, entitled "Studies in the Phosphorescence of Marine Animals," in which he states that the luminosity observed in the case of certain (earth) worms is due to a secretion from the girdle, where special glands exist, and that by the evolution of light there was no perceptible raising of the temperature. In this respect, therefore, the earthworm's glow corresponds with that emitted by the firefly, Noctiluca, and glow-worm. One investigator at least has tested the colour and composition of the luminosity by the spectroscope, and says that it is not uni-coloured or monochromatic, but compounded chiefly of the red and violet rays. Other students regard the substance which produces the light as homogeneous.

In 1838 Eversmann published an article on a night-shining worm in Russian, and in 1871 an English naturalist named Breese delivered an address on the earthworm before the West Kent Natural History Society, from a meagre abstract of which we learn that he had spent some years on the subject of annelid luminosity, having studied it historically from the year 1805, when Viviani wrote on the phosphorescence of the sea, down to the date of his own delivery. According to Breese the luminosity exists in the excreted glutinous material with which the outer skin of the animal is covered.

More than one creature has at different times borne the name of the phosphorescent worm. In 1837 Dugès, a French writer, described a species under this name (*Lumbricus phosphoreus*), with a girdle extending from the 13th to the 16th segments, and a somewhat flattened body behind. After the lapse of exactly half a century this curious creature was examined again, and named by Giard Photodrilus, or the luminous worm. It has eight setæ, just as our common species have, but they are separate, and not in couples. There is no gizzard, nor does the lip dovetail into the segment behind. It is a small, transparent, rose-coloured worm, and decidedly phosphorescent.

In 1843 when the British Association met at Cork, specimens of an annelid were exhibited by Dr. Allman, which he had discovered in the bogs of the south of Ireland, and which was the cause of a luminous appearance. When irritated the worm gave out a phosphorescent light, which is said to have been much increased by exposing the creature to the vapour of alcohol. The light was of that peculiar soft greenish hue which is characteristic of the phosphoresence observed in light-giving animals, and familiar to most readers in connection with the glow-worm. Another gentleman was reported to have observed the same peculiarity in some annelids which exist in the bogs of Connaught. I have been unable to find any recent reference to or confirmation of these curious observations. Ten years later Mr. Henry Cox exhibited an earthworm which was phosphorescent at a meeting of the Literary and Philosophical Society of Liverpool, held November 14, 1853.

While few records of a trustworthy nature respecting the observation of luminous worms in Britain are available, a good deal has been done by our Continental fellow-workers. Vejdovsky, who wrote a very valuable work on the various species of an-

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nelids in 1884, gives us some results of his personal experience, which I believe have never been placed before the English reader. He says that he had the good fortune once at least to observe an interesting case of phosphoresence in connection with the brandling. It was one warm July night in the year 1881, when he was exploring a dung-heap. Naturalists do not usually work with kid gloves and diamond rings. Presently a spot of soft, bluish-white light appeared, which, however, was changeful and unsteady. Now it would disappear, then return anew and shine forth over a larger space, though never with a brilliant hue. He thereupon removed a portion of the manure from the spot where he had observed the luminosity, and found that the light appeared brighter, and shone for a longer time without disappearing, or before it migrated to another spot. By means of a lantern Vejdovsky was able to secure a large number of specimens of the brandling from the dung-heap, which he placed in a vessel for the purpose of subjecting them to careful observation. To his great surprise he found that his finger soon glowed in the darkness with the phosphorescence, which extended generally over the hand where it came into contact with the worms. It was therefore apparent that the luminosity was the product of a fluid secreted by the cutaneous glands, which had attached itself to the hand of the investigator, and now manifested itself in this curious way.

We have an interesting observation on the same subject by Prof. von Stein, which was published at Leipzig in 1883. One evening in the middle of September the Professor was spending some time with a circle of friends at a parsonage not far from Potsdam, when the conversation turned upon phosphorescence and the phenomena of light. Hereupon one of the younger members of the family—who are usually the keenest and most shrewd observers of Nature, and the best friends of the naturalist—observed that there were fountains in the adjoining gardens, the water from which was frequently observed to be full of light-bearing creatures when it was violently agitated. He regarded the affair at first simply as a hoax, or an attempt to make a fool of him—as people are ever ready to do with a hobby-rider—but ascertained eventually that the luminosity was due to the presence of a species of worm which possessed the property of shining when disturbed. As with Vejdovsky, so with Prof. von Stein, the finger which had come into contact with the worm continued to glow for some time after. What species of worm was under observation is not recorded.

It now becomes a question, What end could be served thereby? The philosopher no sooner learns a new fact than he begins to pry into the secret which lies beneath, and stands to it as cause to effect. We have analogy to guide us. The water worms may be compared with the marine animals which produce phosphorescence, while the brandling may be studied in the light of the glow-worm. It may be objected that as worms have no eyes there can be no advantage in their luminosity. But such an argument would be based on the erroneous assumption that a creature without eyes is incapable of receiving impressions from light. That worms are influenced by light is proved both by their habit of avoiding light, and by the experiments which have been carried out by various students. Darwin remarks that as worms are destitute of eyes he at first thought they were quite insensible to light. He found, however, that "light affects worms by its intensity and by its duration." Hoffmeister states that with the exception of a few individuals worms are extremely sensitive to light, and from my own observations I have been able to demonstrate that there are marked differences in the susceptibility of the different species—some being very much more susceptible than others.

Now it follows that if a number of species of worms lived together in one place, as they usually do in a manure heap, it would be a great advantage for a given species to possess a distinguishing feature, such as that of luminosity, to enable two individuals to discover each other's whereabouts, just as the male glow-worm detects the female by the light emitted from her upturned abdomen. We have, moreover, the fact that certain species of earthworm are characterised by a peculiar odour, which must be of great service in preventing promiscuous copulation and hybridity. Though earthworms are destitute of nasal organs they can detect odours, and though sightless they are affected by light.

Viewed in this light a new field of research is opened up which hitherto has been totally unworked, but which may be hoped to yield remarkable results if diligently, patiently, and intelligently tilled.

It would be an easy thing for any one living in the country, with access to an old manure heap, where the brandling (*Allolobophora fœtida*, Sav.) usually abounds, to ascertain whether such luminosity is of common occurrence, and it would be exceptionally valuable to record the period of the year, the state of the atmosphere, the age of the moon, and other data which would enable the specialist to arrive at a satisfactory conclusion. I shall be glad to receive communications, addressed "The Grove, Idle, Bradford," from observers who may find pleasure in such pursuits. HILDERIC FRIEND.

Quaternions and the Algebra of Vectors.

IN a recent number of this Journal (p. 151) Mr. McAulay puts certain questions to Mr. Heaviside and to me, relating to a subject of such importance as to justify an answer somewhat at length. I cannot of course speak for Mr. Heaviside, although I suppose that his views are not very different from mine on the most essential points, but even if he shall have already replied before this letter can appear, I shall be glad to add whatever of force may belong to independent testimony.

Mr. McAulay asks: "What is the *first* duty of the physical vector analyst *quâ* physical vector analyst?" The answer is not doubtful. It is to present the subject in such a form as to be most easily acquired, and most useful when acquired.

In regard to the slow progress of such methods toward recognition and use by physicists and others, which Mr. McAulay deplores, it does not seem possible to impute it to any want of uniformity of notation. I doubt whether there is any modern branch of mathematics which has been presented for so long a time with a greater uniformity of notation than quaternions.

What, then, is the cause of the fact which Mr. McAulay and all of us deplore? It is not far to seek. We need only a glance at the volumes in which Hamilton set forth his method. No wonder that physicists and others failed to perceive the possibilities of simplicity, perspicuity, and brevity which were contained in a system presented to them in ponderous volumes of 800 pages. Perhaps Hamilton may have intended these volumes as a sort of *thesaurus*, and we should look to his shorter papers for a compact account of his method. But if we turn to his earlier papers on Quaternions in the *Philosophical Magazine*, in which principally he introduced the subject to the notice of his contemporaries, we find them entitled "On Quaternions; or on a New System of Imaginaries in Algebra," and in them we find a great deal about imaginaries, and very little of a vector analysis. To show how slowly the system of vector analysis developed itself in the quaternionic *nidus*, we need only say that the symbols S, V, and ∇ do not appear until two or three years after the discovery of quaternions. In short, it seems to have been only a secondary object with Hamilton to express the geometrical relations of vectors,—secondary in time, and also secondary in this, that it was never allowed to give shape to his work.

But this relates to the past. In regard to the present *status*, I beg leave to quote what Mr. McAulay has said on another occasion (see *Phil. Mag.* June, 1892):—"Quaternions differ in an important respect from other branches of mathematics that are studied by mathematicians after they have in the course of years of hard labour laid the foundation of all their future work. In nearly all cases these branches are very properly so called. They each grow out of a definite spot of the main tree of mathematics, and derive their sustenance from the sap of the trunk as a whole. But not so with quaternions. To let these grow in the brain of a mathematician, he must start from the seed as with the rest of his mathematics regarded as a whole. He cannot graft them on his already flourishing tree, for they will die there. They are independent plants that require separate sowing and the consequent careful tending."

Can we wonder that mathematicians, physicists, astronomers, and geometers feel some doubt as to the value or necessity of something so separate from all other branches of learning? Can that be a natural treatment of the subject which has no relations to any other method, and, as one might suppose from reading some treatises, has only occurred to a single man? Or, at best, is it not discouraging to be told that in order to use the quaternionic method, one must give up the progress which he has already made in the pursuit of his favourite science, and go back to the beginning and start anew on a parallel course?

I believe, however, that if what I have quoted is true of vector methods, it is because there is something fundamentally wrong

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